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Coordination Failure in Capacity-then-Price-Setting Games

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Abstract

In capacity-then-price-setting games, soft capacity constraints are planned sales amounts where producing above capacity is possible but more costly. While the subgame perfect equilibrium predicts equal prices, experimental evidence often reveals price discrepancies. This failure to coordinate on equal prices can imply losses, especially when serving demand is obligatory. We compare coordination failure with efficient rationing as well as with compulsory serving of demand, and additionally allow for simultaneous and sequential capacity choices. These treatments lead to a varying severity of the threat of losses. Our experimental results show that (possible) coordination failure affects behavior through two channels: via anticipating as well as via reacting to a loss. While capacities increase in anticipation of losses, prices increase when anticipating losses but decrease after experiencing losses. Coordination failures are more probable after subjects experienced a loss.

Keywords: capacity-then-price competition, loss avoidance, path dependence, sequentiality of decisions, intra-play communication

JEL Classification: C72, C91

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I. Introduction

There is a vast literature on laboratory experiments analyzing collusive behavior of competitors. However, these approaches mostly abstract from the fact that collusion, e.g., coordination on higher than competitive prices, may fail as competitors can undercut collusive prices. In markets with homogeneous goods and capacity constraints the risk of unsuccessful price coordination is especially pronounced because differing prices can lead to a rationing of demand. Setting capacities too low can cause losses if excess demand has to be served whereas too high capacities can cause losses if demand is insufficient to cover the capacity-installation costs. Capacity-then-price competition thus provides a rich setting to study how the anticipation and experience of coordination failure affects market behavior. Our study further varies the timing of capacity choices allowing for "leading by example" which is known to stimulate coordination in experimental markets.

Kreps and Scheinkman (1983) have been the first to theoretically analyze a capacity-then-price-setting game in a homogeneous market. Among others, Güth (1995), Maggi (1996), and Boccard and Wauthy (2000, 2004) loosen their interpretation of "capacity" by allowing to sell beyond initial capacity precommitment, albeit at higher marginal costs. Rather than a prohibitive increase of marginal costs at the capacity limit, "soft" capacity constraints—in case of higher than anticipated demand—allow firms to sell more than their planned sales amounts. When firms are obliged to serve demand—possibly at higher unit costs—rationing, demand spillovers, and mixed strategies can be avoided. In a setup with soft capacity constraints and sellers' obligation to serve demand, too low prices can force sellers to sell more than planned, whereas too high prices can leave them with no demand to cover sunk capacity installation costs. Both types of coordination failures imply a "threat of losses."

In the context of capacity-then-price-setting games, simultaneous versus sequential capacity choices has been found to enhance collusion. Huck et al. (2001) compare simultaneous versus sequential quantity competition and also distinguish between random-strangers and partners-matching. Only for partners-matching both, simultaneous and sequential quantity competition, do induce collusion, there are no collusion effects for random-strangers-matching. Regarding the substantial behavioral impact of loss avoidance, other studies report that participants prefer even more risky strategies with the potential to avoid losses over those which trigger losses with certainty (see, e.g., Rydval and Ortmann, 2005; Feltovich et al., 2012; Cachon and Camerer, 1996; Tversky and Kahneman, 1979, 1991).

Our approach differs from these contributions in several ways: in capacity-then-price competition based on fixed pair matching, participants either simultaneously or sequentially choose capacities before simultaneously setting prices. To vary the threat of losses imposed by coordination failure, participants either confront efficient rationing or compulsory serving of excess demand (based on soft capacity constraints). While these conditions are implemented between-subjects, additionally "cheap talk" or "no communication" after capacity but before price choices is implemented as a within-subjects variation. However, as cheap talk as such does not affect the threat of losses, we focus only on the data of conditions without cheap talk in the following (for an analysis of cheap talk versus no communication see Güth et al., 2018). The considered variations allow for a thorough analysis of possibly path-dependent price and capacity choices in multi-stage games.

The rest of the paper is organized as follows. Section II. analyzes the theoretical model and derives the benchmark hypotheses. Section III. introduces the experimental design. Section IV. describes and analyzes the data and discusses the results. Section V. concludes.

II. The theoretical benchmark model

We consider a two-stage capacity-then-price-setting game with two firms $i = 1, 2$ installing capacities $\bar{q}_i$, indicating how much they intend to produce and sell. For demand amounts q_i not exceeding these levels, the constant unit cost of installing capacity are c_K and the constant unit cost of production are c_P. When demand exceeds these planned levels, firms can expand their supply, but only at an additional unit cost $\vartheta \geq 0$.[1] Thus, total unit costs amount to

$$\tilde{c} = \begin{cases} c & \text{if } q_i \leq \overline{q}_i \\ c + \vartheta & \text{if } q_i > \overline{q}_i \ , \end{cases}$$

where $c \equiv c_P + c_K$.[2] We restrict our analysis to a homogeneous market with the linear demand function

$$D(p) = \alpha - p \ ,$$

where $\alpha (> c + \vartheta)$ indicates market size.

We distinguish two basic scenarios: (i) *Efficient rationing.* Rationing is efficient and the additional cost of a subsequent increase in capacity is prohibitively high, i.e., capacity constraints are binding and demand above capacity is not served. In case of differing prices, the firm setting the lower price thus serves demand only up to its capacity, whereas the firm setting the higher price serves residual demand at its higher price. (ii) *Compulsory serving of excess demand.* Excess demand must be served so that the firm charging the lower price has to satisfy all demand at its price which may likely imply producing and selling above capacity. Correspondingly, the firm setting the higher price sells nothing. Based on these equilibrium prices for both scenarios, we will discuss the causes and consequences of coordination failure in more detail.

The theoretical benchmark solutions prove to be the same for both scenarios: depending on the sequentiality of the decision process, either the Cournot (1838) or the Stackelberg (1934) solution is implied by the subgame perfect equilibrium of the capacity-then-price-setting game. For the market clearing prices $p^* = \alpha - \overline{q}_i - \overline{q}_j$, the reduced-form profit functions in the first stage are

$$\pi^i = (\alpha - \overline{q}_i - \overline{q}_j - c)\overline{q}_i \ ; \qquad i, j = 1, 2, \quad i \neq j \ .$$

[1] As an alternative approach, Cabon-Dhersin and Drouhin (2014) consider the case of a convex short-term cost function leading to soft capacity constraints and tacit collusion.

[2] Abbink and Brandts (2008) as well as Andersson et al. (2014) use another framework and study pricing behavior in case of increasing marginal costs.

The profit maximizing capacities depend on the rules of the game.

Efficient rationing

Efficient rationing means that the most eager consumers are served first. When the competitor j has installed a capacity $\bar{q}_j$, the residual demand for firm i is given by

$$D_i(p_i) = \begin{cases} \alpha - p_i - \bar{q}_j & \text{if } p_i \geq p_j \\ \alpha - p_i & \text{if } p_i < p_j \ . \end{cases}$$

In the second stage of the game, given the capacities $\bar{q}_1$ and $\bar{q}_2$, the market clearing prices $p^* = \alpha - \bar{q}_1 - \bar{q}_2$ constitute a Nash equilibrium (in pure strategies) if no firm can do better by unilaterally deviating. A price cut to $p < p^*$ leads to a lower profit if the reduced price is lower than the total unit cost $\tilde{c} = c + \vartheta$ after a subsequent capacity expansion, i.e.,

$$p < c + \vartheta \tag{1}$$

A price increase to $p > p^*$ leads to a lower profit $\pi^i = p_i(\alpha - p_i - \bar{q}_j)$ if $\partial\pi^i/\partial p_i\big|_{p_i=p^*} = \alpha - 2p^* - \bar{q}_i + \bar{q}_j \leq 0$, i.e.

$$2\bar{q}_i + \bar{q}_j \leq \alpha \tag{2}$$

for $i = 1,\, 2,\, j \neq i$. Given that $p^* = \alpha - \bar{q}_1 - \bar{q}_2$ is an equilibrium in the second stage, the reduced-form profit functions in the first stage read $\pi^i = (\alpha - \bar{q}_i - \bar{q}_j - c)\bar{q}_i$. We distinguish between simultaneous and sequential capacity choices.

Simultaneous capacity choices: Maximizing these profit functions with respect to the capacities leads to the equilibrium capacities

$$\bar{q}^c = (\alpha - c)/3 \tag{3}$$

which coincide with the Cournot quantities. In the second stage, both firms set the prices

$$p^c = c + (\alpha - c)/3 \tag{4}$$

and realize the profits

$$\pi^c = (\alpha - c)2/9. \tag{5}$$

Equation 3 shows that condition 2 is generally satisfied in equilibrium. Equation 4 shows that condition 1 is satisfied if $\vartheta > (\alpha - c)/3$. The parameter values in our experiment, $\alpha = 200$, $c = 80$, and $\vartheta = 40$ satisfy this equilibrium condition.[3] The market outcome for this parameter constellation is $\bar{q}^C = 40$ and $p^C = 120$.

Sequential capacity choices: The sequential capacity setting features one firm as the leader L who first determines his capacity $\bar{q}_L$, which can be observed by the follower F who then chooses his capacity $\bar{q}_F$ second. As will be shown, in the third stage of the game, the prices $p^S = \alpha - \overline{q}_L - \overline{q}_F$ prove to be equilibrium prices. Therefore, in the second stage the follower maximizes his profits

$$\pi^F = (\alpha - \overline{q}_L - \overline{q}_F - c)\overline{q}_F$$

by setting $\overline{q}^F = (\alpha - c - \overline{q}_L)/2$. Anticipating this reaction, in the first stage, the leader maximizes his profit

$$\pi^L = (\alpha - c - \overline{q}_L)\overline{q}_L/2$$

by choosing $\overline{q}_L = (\alpha - c)/2$. The follower reacts according to $\overline{q}_F = (\alpha - c)/4$, such that the prices, independently charged by both of the firms, are

$$p^S = c + (\alpha - c)/4 \ ,$$

leading to the profits

$$\pi^L = (\alpha - c)^2/8$$

[3] In case of $\vartheta < (\alpha - c)/3$, the equilibrium prices are $p = c + \vartheta$.

and

$$\pi^F = (\alpha - c)^2/16 ,$$

respectively. In order for prices p^S to be subgame perfect, firms must not gain by unilaterally deviating. There is no incentive for a firm to undercut p^S if the marginal cost of producing additional units, $c + \vartheta > p^S$, is higher than $p^S = (\alpha + 3c)/4$, i.e.,

$$\vartheta > (\alpha - c)/4 . \tag{6}$$

Let us now derive the condition where efficient rationing does not induce a firm to *raise* the price above p^S. In the final stage of the game, firm i's (net) profit from setting a price $p_i \geq p^S$ is

$$\pi^i = (p_i - c_P)(\alpha - p_i - \overline{q}_j) .$$

Its derivative at $p_i = p^S$,

$$\alpha - 2p^S - \overline{q}_j + c_P ,$$

has to be non-positive for p^S to qualify as an equilibrium price. Obviously, the more restrictive case for this critical condition is that $j = F$, i.e., the leader $i = L$ deviates. Therefore, the price p^S constitutes an equilibrium if $\alpha - 2p^S - q_F + c_P \leq 0$ is satisfied. Substituting for $p^S = (\alpha + 3c)/4$ and $\overline{q}_F = (\alpha - c)/4$ and taking into account that $c = c_K + c_P$ this implies the condition

$$\alpha - 5c_K - c_P \leq 0 . \tag{7}$$

The parameter values in the experiment, $\alpha = 200$, $c_K = 80$, $c_P = 0$, and $\vartheta = 40$ satisfy the equilibrium conditions (6) and (7). The market outcome for this parameter constellation is $\bar{q}^L = 60$, $\bar{q}^F = 30$, and $p^S = 110$.

Compared to the simultaneous game, sequential capacity choices lead to higher total capacities ($\bar{q}_L + \bar{q}_F = 3(\alpha - c)/4 > 2\bar{q}^c = 2(\alpha - c)/3$) and lower prices

($p^S = c + (\alpha - c)/4 < p^c = c + (\alpha - c)/3$), i.e., sequentiality of capacity choices is more competitive.

Collusion, in the sense of both sellers sharing the monopoly profit, implies $\bar{q}_1 = \bar{q}_2 = \bar{q}^K = 30$ and $p_1 = p_2 = p^K = 140$ when sharing equally. We will view lower total capacities and higher prices as an indicator of collusive behavior.

Compulsory serving of excess demand

If firms have to serve excess demand, for instance, since the cost of turning down customers is very high, the equilibrium outcomes continue to apply. There is no incentive for a firm to charge a price higher than the equilibrium price because this would result in no demand at all. In case of a unilateral price reduction, the assumption $\vartheta \geq (\alpha - c)/3$ implies that the unit cost of producing above the planned capacity ($c + \vartheta$) is higher than any price $p \leq p^C$ so that any price reduction below p^C or p^S is unprofitable, regardless whether capacity decisions are simultaneous or sequential. Therefore, for the parameter values used in our experiment, the unique subgame perfect equilibria are the same as in the case of efficient rationing.

We thus state

Hypothesis 1 *Sequentiality of capacity choices induces fiercer competition, i.e., higher total capacities and lower prices.*

Coordination failure: In the theoretical benchmark model, there are no rational incentives for different capacity or price choices in case of efficient rationing or compulsory serving. However, compulsory serving easily leads to losses if subjects fail to coordinate on the same price as this distributes demand unequally between them. With unequal prices and compulsory serving, the one with the lower price has to serve the entire demand. If demand exceeds capacity, this means producing above capacity at a higher cost. The seller with the higher price, in turn, faces no demand at all and earns nothing to cover (sunk) capacity installation cost. With efficient rationing, the failure to coordinate prices bears a weaker threat of losses: The seller with the lower price has to serve demand only up to his capacity limit. The seller with the higher price, however, has to fear that residual demand is insufficient to cover capacity installation cost. The threat of losses is thus stronger with compulsory serving as compared to efficient rationing which might affect the behavior of participants in different ways.

In the capacity-then-price-setting game, the two potential causes for a loss are thus *excess demand* and *insufficient demand*. In case of failure to coordinate prices, excess demand results for the subject with the lower price, whereas demand is insufficient for the subject with the higher price. In the experiment, we can identify which type of coordination failure causes a loss. Thus, we can investigate whether subjects react differently to the loss type they have experienced. Experimental studies show that experiencing losses induces attempts to subsequently avoid (or reduce the risk for) them (see, e.g., Tversky and Kahneman, 1991; Cachon and Camerer, 1996; Feltovich et al., 2012).[4] In our experiment, loss avoiding strategies could induce subjects, who experienced excess demand, to increase capacities to mitigate the risk of excess demand, or they could induce subjects to increase their prices to avoid having the lower price. This would be in line with the literature suggesting more risky behavior after a loss (see, e.g., Cachon and Camerer, 1996) as a larger capacity and higher price could avoid the loss which would result from playing it safe, i.e., choosing a low capacity but a high price. Behaviorally this suggests

Hypothesis 2 *Experiencing a loss, caused by excess demand, induces higher capacities as well as higher prices.*

However, subjects who experienced insufficient demand could decrease capacities to reduce capacity installation cost and decrease prices to avoid having the higher price. This loss avoiding strategy gives us our second behavioral hypothesis.

Hypothesis 3 *Experiencing a loss, caused by no, or insufficient demand, induces lower capacities as well as lower prices.*

In case of failed coordination one out of a pair has the too high and the other the too low price, i.e., price reactions to avoid future losses move in opposite directions. If, e.g., the experience of a loss caused by no or insufficient demand induces the subject with the too high price to decrease his price, the other subject—who has a too low price and possibly experienced a loss caused by excessive demand—increases

[4] There is, however, also evidence that previous losses trigger more risk taking if the risky alternatives can eliminate the loss, see, e.g., Thaler and Johnson (1990).

his price, coordination failure would become more probable. Such a scenario would prevail if the above hypotheses for the case of compulsory serving hold: if coordination failure leads to excessive demand for the subject with the too low price and to no demand at all for the subject with the too high price. Then past loss experiences would make future coordination failures more likely. The same is true in the treatments with efficient rationing where failed coordination leaves one out of a pair facing insufficient demand due to his price being too high. If he reacts by lowering his price, as predicted, where the other would not change his price, coordination again becomes less probable. Summarizing we state

Hypothesis 4 *Experiencing a loss increases the probability of failures to coordinate prices.*

III. Experimental design

Capacity choices are usually observable in terms of factory size, number of production and assembly lines, etc. Therefore it is realistic to assume that capacity choices become publicly known. As analyzed above, capacity choices in the experiment may be independent (IC) or sequential (SC). A second condition distinguishes efficient rationing (R) and compulsory serving (CS). While treatments R and CS are implemented between subjects, the (im)possibility of price messages is varied within-subjects via distinguishing

(M) price messages after capacity and before price choices: Each seller $i = 1, 2$ sends a non-binding message (containing only a number) about his choice p_i, then both sellers, after simultaneously receiving the other's price message, choose their sales prices, p_1 and p_2; and

(N) no message exchange.

Only the order of M and N is varied between subjects referred to as M-N and N-M treatments with the obvious interpretation. Thus altogether eight treatments (k, l, m) with $k \in \{\text{R}, \text{CS}\}$, $l \in \{\text{IC}, \text{SC}\}$ and $m \in \{\text{M-N}, \text{N-M}\}$ (see Table 1) are implemented "between subjects" in a 2x2x2-factorial design: IC versus SC, R versus CS, and M-N versus N-M.

Table 1: The eight treatments

	Independent capacity (IC)	sequential capacity (SC)
Efficient rationing (R)	M-N	M-N
	N-M	N-M
Compulsory serving (CS)	M-N	M-N
	N-M	N-M

These treatments are implemented as finitely repeated games: The same pair of participants stayed together for only four rounds of the capacity-then-price setting game being aware of the number of rounds.[5] This allows for cooperation via low capacities as well as high sales prices, in the M-case via communication, and, additionally, in the treatments with sequential capacity choices via "leading by example." Rather than implementing long-finite horizon games with the same partner, we successively ran three repeated games of four rounds each based on matching groups with four participants of which two are newly matched per game, i.e., in condition M or N one successively confronts the three other participants in one's matching group and interacts with each of them across four rounds.[6] Altogether, participants played 24 rounds of the capacity-then-price setting game, consisting of two 12-round phases covering the within-subjects variation $m \in \{\text{M-N}, \text{N-M}\}$, see Table 1.

In the SC conditions a repeated game began with an initial random role assignment of being the first or second mover in capacity choice.[7] To ensure that participants thoroughly understood the experimental tasks, all sessions began with control questions and a trial round.[8] Unlike Anderhub et al. (2003), we have refrained from implementing more rounds of pricing (sub)games for constant but endogenously selected capacity constellations. Our reason for doing so is that we were interested in

[5]Since each round is composed of at least two stages, there are more interactions than rounds.

[6]We formed new matching groups when moving from condition M (N) to N (M).

[7]We did not try to influence how often a participant in the SC-conditions encounters the two roles but let it be decided randomly for each pair. We expect no differences in behavior when being first or second in capacity choices more often.

[8]In the trial round, participants played against a "robot" programmed to choose benchmark capacities and prices. This could imply an implicit demand effect to behave as theoretically predicted. However, we very rarely observe benchmark play in the experimental data. In the SC treatments, participants played one trial round in the role of the leader and one in the role of the follower (in view of the richer stage structure more familiarity with the experimental scenario seemed advisable).

"capacity constellation and price vector" data to distinguish how different capacity constellations affect prices without confounding learning and reputation dynamics.

Throughout the experiment, payoffs were calculated in Experimental Currency Units (ECU) converted into euro at a given and known exchange rate (10,000 ECU = 1 euro). In addition to their show-up fee of 15 euros, participants were paid for 10 random rounds (5 from each of the two phases) and received the reward for a lottery question in the post experimental questionnaire on risk tolerance (see Holt and Laury, 2002).[9] The experiment was programmed in *z*-tree (Fischbacher, 2007). We ran 16 sessions in total, two for each treatment, 15 with 32, and one with 28, participants, all students attending a German university. As we consider only N-conditions in this paper, i.e., only the between-subjects variations, this gives us 508 participants making 12 capacity and 12 price decisions each.
On average, sessions lasted about 108 minutes, and payments to participants amounted, on average, to 17.41 euros and ranged from 12.80 to 20.30 euros.

IV. Experimental results

Descriptive evidence

For the descriptive evaluation of our results we cluster our experimental data at the matching group level.[10] Figure 1 depicts the chosen, as well as the benchmark, capacity-price pairs in the four treatments without price messages. Evidently—as expected—the relationship between prices and capacities is negative, i.e., participants understood the basic intuition that lower capacities allow for higher prices. Overall, actual behavior differs from the benchmark: only 3.09% of decisions in the N treatments lie within a 10% range of the predicted capacity-price pairs. In the treatments with compulsory serving (CS) capacity-price pairs move south-east,

[9] Pilot sessions showed that some participants accumulated substantial losses which we neither wanted them to pay out-of-pocket nor to work off by clerical work. In our view, such accumulated losses are not a result of poor understanding, but rely on questionable heuristics such as being able to dominate the market by choosing a large capacity.

[10] Participants could exit the market when overburdened with the experimental task. As such choices are not the focus of our analysis we exclude them from our sample. Dropouts in the N-condition amount to 1.8% of all 3072 decisions made in the R and 32.9% of all 3024 decisions made in the CS condition. The striking difference in dropout rates can be explained by the substantially higher risk in treatment CS. The fact that less decisions were made in the CS condition is caused by one out of four sessions consisting of only 28 participants.

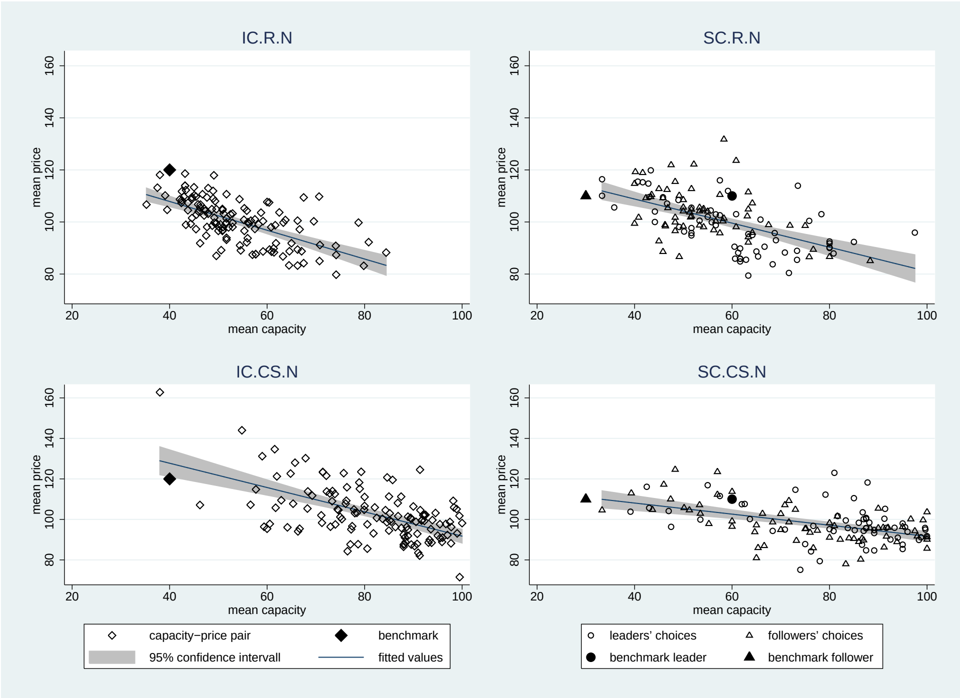

Figure 1: Capacity-then-price choices and benchmark results in the N treatments

i.e., participants in fear of negative payoffs choose higher capacities in combination with lower prices to mitigate the risk of selling above capacity. Excluding the CS treatments, the percentage of decisions within a 10% range of the predicted values increases to 5%, suggesting that the threat of losses plays a substantial role.[11]

Regarding Hypotheses 2, 3, and 4, we are interested in coordination failures leading to losses. Table 2 shows the percentage of price coordination failures: unequal prices lead to losses relative to all price vectors. As expected, we observe a higher percentage of losses caused by coordination failure (between 77.9% and 78.0%) in treatments with compulsory serving than in treatments with efficient rationing (between 45.3% and 46.9%).

Table 2: Percentage of price coordination failures leading to losses relative to all price decisions in condition N

	Independent capacities	sequential capacities
Efficient rationing	46.9	45.3
Compulsory serving	77.9	78.0

A more differentiated view on the development of coordination failures over time

[11] By interpreting an ϵ-range around equilibrium values as "optimal" we follow Radner (1980).

shows that experience plays a decisive role: if the N-condition is implemented in the first phase of the experiment (rounds 1-12), the percentage of coordination failures in treatments with and without compulsory serving (CS) converges over time, whereas if the N-condition is implemented in the second phase of the experiment (rounds 12-24), coordination failures clearly occur more often in treatments with compulsory serving. Thus, experienced subjects react differently to the high threat of losses imposed by the CS-treatment: not only do they have a better understanding of the consequences of failed coordination due to their experience of repeatedly playing the game, but they also have possibly endured more losses than inexperienced subjects.

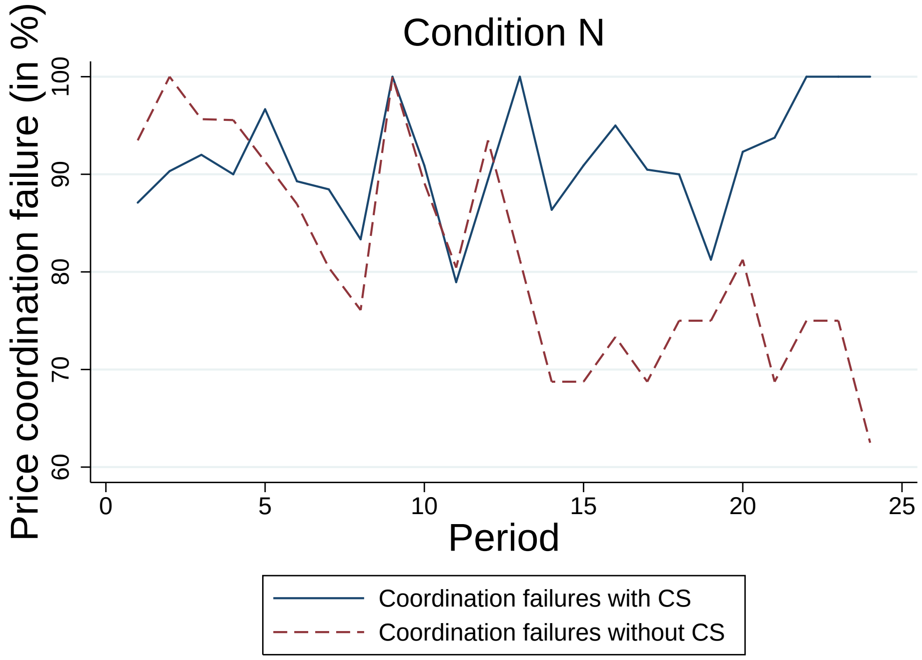

Figure 2: Coordination failures over time

Our hypotheses regarding the effects of loss experience propose that different causes for a loss, i.e., excess, insufficient, or no demand, trigger different loss-preventing strategies. Figure 3 depicts all cases of price coordination failures leading to a loss, distinguishing the type of coordination failure that caused the loss, i.e., a too high or too low price. The percentages are calculated with respect to the overall number of coordination failures leading to a loss in the respective treatment.[12]

[12]Note that losses also occurred in cases with successful price coordination. With respect to the overall number of price choices leading to a loss these amount to 4.4% in treatment R.IC, 5.7% in treatment R.SC, 7.8% in treatment CS.IC, and 6.8% in treatment CS.SC.

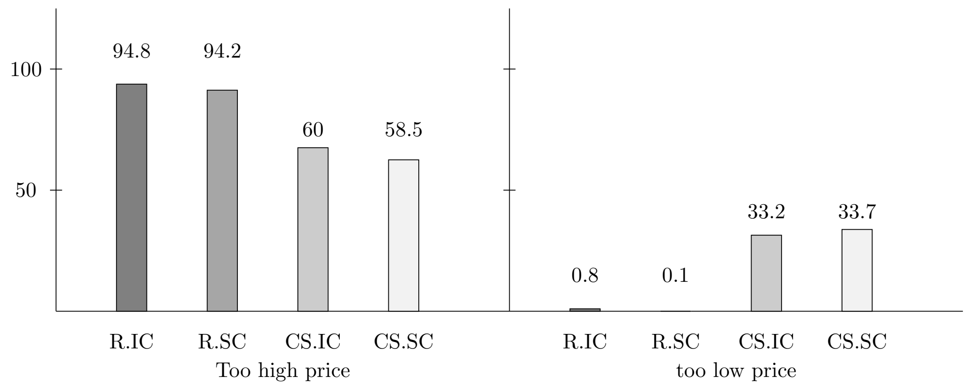

Figure 3: Percentages of coordination failures leading to a loss relative to all coordination failures leading to a loss in the respective treatment

Evidently, in most cases a too high price led to a loss. Distinguishing conditions, we observe a very high percentage of high-price coordination failures for efficient rationing (around 94%) and a fairly high percentage for compulsory serving (between 58.5% and 60.0%), whereas there is hardly any difference for the other between-subjects variation, independent versus sequential capacity choices (see Figure 3). Recall that a too high price in the condition with compulsory serving leads to no demand, whereas in the condition with efficient rationing it (possibly) leads to insufficient demand. A too low price, however, can lead to excess demand with compulsory serving and has no consequence in case of efficient rationing. This explains the extremely high percentage of cases where a too high price caused a loss, along with the very low percentage of cases where a too low price caused a loss in treatments with efficient rationing. In treatments with compulsory serving, causes for a loss are more heterogeneous: a higher percentage of cases is caused by too high prices (between 58.5% and 60.0%), i.e., no demand, as compared to too low prices (around 33%), i.e., excess demand. These descriptive results will be tested empirically below.

Test of Hypotheses

For the econometric evaluation of our experimental data, the between-subjects variations are evaluated using ordinary least square (OLS) models. We account for the problem of non-independent observations by clustering standard errors at the matching group level. Given that 508 subjects made capacity and price decisions in 12 subsequent rounds, observations amount to 2028 for the CS-treatment and to 3016 for the R-treatment, after deleting dropouts (see Footnote 10).

Hypothesis 1 proposes that treatments with sequential capacity choices (SC) lead to fiercer competition, i.e., higher capacities ($\bar{q}_{own}$, $\bar{q}_{other}$) and lower prices ($\bar{p}_{own}$, $\bar{p}_{other}$). We evaluate this effect controlling for the between-subjects variation *efficient rationing* versus *compulsory serving* (CS), for competition experience (Exp), for the final round *fRound*, and the *game*. As subjects interacted in six games lasting four rounds each, i.e., *fRound* controls for endgame effects, whereas *game* (varying from 1 to 6) controls for effects of learning to play repeated games. Subjects have competition experience (Exp) whenever the N-condition is introduced in the second phase of the experiment, i.e., subjects have already experienced 12 rounds of the capacity-then-price-setting game. We additionally include the lagged capacity decision ($\bar{q}_{own}(t-1)$) and the lagged competitor's capacity decision ($\bar{q}_{other}(t-1)$) and test whether leader and follower behavior differs for the treatments with sequential capacity choices by including a *leader* dummy. As Hypothesis 1 refers to capacities and prices, we estimate a model with capacities and one with prices as the dependent variable. For the estimation of prices, we include lagged price choices. Estimation results are reported in Tables 3 and 4 where the right columns report results for the subsample with sequential capacity choices. Due to the inclusion of lagged variables the number of observations is reduced to 4423 for the complete sample (left column) and to 2216 for the subsample of the SC-treatment (right column). Standard errors are clustered at the matching group level.

For both, capacity and price choices, Tables 3 and 4 report a significantly positive correlation between prior and present choices. A higher capacity (price) in $t-1$ triggers a higher capacity (price) in t. Prior choices of the competitor have the same effects on the own present choice. This indicates that over time choices move in the same direction: a high capacity of the competitor in $t-1$ leads to a significantly higher capacity choice in t, and a high price of the competitor in $t-1$ leads to a significantly higher price choice in t.

While *compulsory serving* has a significantly positive effect on capacities and prices (which we will discuss in detail below), capacities and prices in treatments with

Table 3: Effect of sequentiality (SC) on capacity choices

	Capacities			
Variable	**Coeff.**	**(Std. Err.)**	**Coeff.**	**(Std. Err.)**
$\bar{q}_{own}(t-1)$	0.419***	(0.028)	0.452***	(0.035)
$\bar{q}_{other}(t-1)$	0.097***	(0.017)	0.098***	(0.023)
SC	0.044	(1.012)		
$Leader$			2.096**	(0.859)
CS	12.166***	(1.336)	10.006***	(1.808)
Exp	-0.503	(1.483)	-1.060	(2.101)
$fRound$	-1.660*	(0.928)	-3.292**	(1.396)
$Game$	-0.522	(0.325)	-0.445	(0.435)
Constant	28.183***	(2.695)	25.671***	(3.962)
Observations	4423		2216	
R^2	0.36		0.356	
Sample used	all treatments		SC, CS, R treatment	

Significance levels : * 10% ** 5% *** 1%
Standard errors clustered at matching group level

sequential capacity choices (SC) are not significantly different from those in treatments with simultaneous capacity choices. When including only the subsample of sequential capacity choices, we observe that leaders choose significantly higher capacities than followers, i.e., the *leader*-dummy has a significantly positive effect (see right hand column in Table 3). This effect, however, does not carry over to price choices (see right hand column in Table 4). Thus, while our experimental data does not directly support Hypothesis 1, we find evidence for an intention of leaders to induce a fiercer competition via higher capacities which is in line with Hypothesis 1. We state

Result 1 *Leaders choose significantly higher capacities than followers.*

Our control variable for endgame effects ($fRound$) has a significantly negative impact indicating that subjects choose lower prices and capacities in the final round of interacting with the same partner.

Hypotheses 2 and 3 propose that the *consequences* of past choices, i.e., a resulting profit or loss, affect present choices. The effects of compulsory serving compared to efficient rationing are accounted for by evaluating subsamples with either condition separately, i.e., $CS = 0$ and $CS = 1$.

Coordination failure results if subjects choose differing prices. The *extent* of the price difference, however, is not decisive for the consequence of a coordination failure which is either excess or insufficient demand. Chosen prices, not the difference

Table 4: Effect of sequentiality (SC) on price choices

	Prices			
Variable	**Coeff.**	**(Std. Err.)**	**Coeff.**	**(Std. Err.)**
$\bar{q}_{own}$	-0.448***	(0.029)	-0.376***	(0.031)
$\bar{q}_{other}$	-0.154***	(0.018)	-0.157***	(0.023)
$p_{own}(t-1)$	0.162***	(0.022)	0.183***	(0.029)
$p_{other}(t-1)$	0.062***	(0.016)	0.072***	(0.023)
SC	0.016	(0.912)		
$Leader$			-0.123	(0.675)
CS	10.338***	(1.391)	5.751***	(1.346)
Exp	1.368	(1.359)	1.348	(1.707)
$fRound$	-1.390**	(0.607)	-1.257	(0.917)
$Game$	-0.385	(0.357)	-0.722	(0.456)
Constant	113.822***	(4.172)	109.012***	(6.449)
Observations	4423		2216	
R^2	0.335		0.339	
Sample used	all treatments		SC, CS, R treatment	

Significance levels : * 10% ** 5% *** 1%
Standard errors clustered at matching group level

between them, determine whether the resulting revenue, if any, is sufficient to cover capacity installation cost. The regression includes price choices of the prior period, $p_{own}(t-1)$ and $p_{other}(t-1)$. For all coordination failures resulting in a loss in the prior period, we create dummy variables for the two types of coordination failure: *too low p* indicating that a too low price led to a loss, $p_{own}(t-1) < p_{other}(t-1)$, and *too high p* indicating a too high price led to a loss, $p_{own}(t-1) > p_{other}(t-1)$. As control variables we further include own and other's capacity decisions, endgame effects ($fRound$), and experience in playing repeated games ($game$). Due to the inclusion of lagged variables the number of observations is reduced to 2852 for the subsample with efficient rationing (left column) and to 1571 for the subsample with compulsory serving (right column). Estimation results with price choices as dependent variable are reported in Table 5. Estimation results for capacities as dependent variable are reported in the Appendix.

Capacities, lagged price choices, and the control variable for endgame effects, display the same significant effects as discussed above. Hypothesis 2 predicts a positive effect of experiencing a coordination failure caused by a too low price. As a too low price affects demand only for the condition with compulsory serving, this type of coordination failure should have an effect for this condition only. Estimation results reveal that a too low price in the prior period has no effect on prices, other

Table 5: Effect of price coordination failures on price choices

	CS= 0		*CS*= 1	
Variable	**Coeff.**	**(Std. Err.)**	**Coeff.**	**(Std. Err.)**
$\bar{q}_{own}$	-0.427***	(0.029)	-0.502***	(0.053)
$\bar{q}_{other}$	-0.228***	(0.022)	-0.049*	(0.029)
$p_{own}(t-1)$	0.172***	(0.030)	0.142***	(0.036)
$p_{other}(t-1)$	0.050**	(0.025)	0.066**	(0.028)
Too high p	-0.755	(0.863)	-2.469**	(1.180)
Too low p	-19.598	(12.056)	-1.640	(1.682)
Exp	0.485	(1.581)	2.874	(2.380)
fRound	-1.603**	(0.710)	-1.125	(1.117)
Game	-0.552	(0.376)	-0.281	(0.748)
Constant	117.394***	(5.292)	123.780***	(7.389)
Observations	2852		1571	
R^2	0.333		0.349	

Significance levels : * 10% ** 5% * * * 1%
Standard errors clustered at matching group level
Includes SC, IC, CS, and R treatment

than predicted. We also find no significant effects of price coordination failure on capacities (see Appendix). However, the results in Table 3 indicate a very strong and significantly positive effect of the dummy *compulsory serving* on capacities. This indicates that the mere threat of losses caused by a too low price and the resulting excess demand is sufficient to induce subjects to install significantly higher capacities than in treatments with efficient rationing. This strong treatment effect can explain why we see no effect of coordination failures on capacities. We state

Result 2 *The threat of having to serve excess demand induces higher capacities.*

Regarding prices, Hypothesis 3 predicts a negative effect of experiencing a coordination failure caused by a too high price. As a too high price affects demand in the condition compulsory serving (no demand) and in the condition efficient rationing (insufficient demand) this type of coordination failure could have an effect for both conditions. However, estimation results only partly support this: a *too high* price in the prior period leads to a significantly lower price in the present period only for the CS-treatment where a too high price leads to no demand at all. Thus, subjects who experienced a loss caused by no demand choose lower prices to prevent having a too high price in the present period. We conclude

Result 3 *Experiencing a loss due to no demand induces lower prices.*

Hypothesis 4 predicts that experiencing a loss increases the probability of a coordination failure. To test this, we run a probit estimation with the dummy *fail* as the dependent variable taking unit value whenever a pair failed to coordinate prices. Explanatory variables are past loss experiences either caused by a *too low* or a *too high* price. Additionally we control for capacity decisions, past price choices, the SC-treatment, competition experience (*exp*), endgame effects ($fRound$), and learning (*game*). Note that the number of observations is reduced to 2852 for $CS = 0$ and 1571 for $CS = 1$ due to the inclusion of lagged variables. Estimation results are summarized in Table 6.

Table 6: Probability of coordination failures

	CS= 0		CS= 1	
Variable	**Coeff.**	**(Std. Err.)**	**Coeff.**	**(Std. Err.)**
Too high $p(t-1)$	0.292***	(0.094)	0.245**	(0.122)
Too low $p(t-1)$			0.351***	(0.130)
$\bar{q}_{own}$	0.002	(0.002)	0.004**	(0.002)
$\bar{q}_{other}$	0.002	(0.002)	0.003*	(0.002)
$p_{own}(t-1)$	-0.007***	(0.002)	0.006***	(0.001)
$p_{other}(t-1)$	0.001	(0.002)	0.005**	(0.002)
SC	-0.261***	(0.101)	-0.037	(0.122)
Exp	-0.415**	(0.169)	-0.138	(0.261)
$fRound$	-0.077	(0.081)	0.178	(0.137)
Game	0.023	(0.048)	-0.040	(0.088)
Constant	1.289***	(0.339)	-0.155	(0.565)
Observations	2852		1571	
Log-likelihood	-1041.594		-435.749	
$\chi^2_{(9)}$	36.152		32.442	

Significance levels : $*$ 10% $**$ 5% $***$ 1%
Standard errors clustered at matching group level
Includes SC, IC, CS, and R treatment

As predicted, coordination failure is significantly more probable if subjects experienced losses in the past. The strongest effect is caused by a too low price in the CS-treatment which results in excessive demand. Subjects who experienced excessive demand resulting in a loss, face a 35% higher probability that price coordination will fail again in the subsequent period. This is followed by losses caused by no demand in the R-treatment causing a 29% higher probability of coordination failure. Finally, subjects who experienced insufficient demand in the CS-treatment face a 24% higher probability that coordination will fail again. We summarize these results in

Result 4 *Loss experience increases the probability of failures to coordinate prices.*

Concerning our control variables we find rather weak effects of capacity and past price decisions, but a strong treatment effect of sequential capacity decisions (SC) as well as a significantly negative effect of competition experience. Sequential capacity decisions seem to simplify price coordination through the possibility of "leading by example" whereas competition experience helps subjects to coordinate prices.

V. Conclusion

We have theoretically and experimentally explored capacity-then-price setting games via letting fixed pairs of participants play four rounds of either simultaneously or sequentially choosing capacities before simultaneously determining their sales prices. This setting allowed us to identify the type of coordination failure causing a loss, too low or too high a price. Depending on the treatment of serving demand, i.e., whether the seller with the lower price has to serve the entire demand or not, coordination failures have more or less severe consequences. In case of "compulsory serving" too low prices can induce excess demand whereas too high prices yield no demand. In the experiment, the latter type of coordination failure more often led to losses than too low prices. Further, "compulsory serving" via its threat of having to serve excess demand induced larger capacities to an extent that no experience effects of losses are visible. Prices, however, react to the loss experiences caused by too high prices (no demand) which let subjects decrease their sales prices.

With efficient rationing, coordination failures had less severe consequences: too low prices hardly ever led to a loss as one had to sell only up to the capacity limit, whereas too high prices with insufficient demand almost always led to a loss. Loss avoiding strategies thus induced path-dependent pricing behavior only in case of compulsory serving: experiencing a loss caused by no demand let subjects lower their prices. However, the positive treatment effect of compulsory serving indicates that the anticipation of a possible loss induces subjects to choose higher prices than in treatments with efficient rationing. Altogether prices are affected through two channels: via anticipating possible losses as well as via reacting to past losses, whereas capacities are affected so substantially by the anticipation of losses that loss experience becomes insignificant. Overall, the probability that coordination of prices fails increases with the experience of losses.

Our findings shed new light on how loss experiences affect market behavior. In line with earlier work identifying a "rationalizing" effect of losses (Cachon and Camerer, 1996; Feltovich et al., 2012) participants, confronting (a risk of) losses, prefer "safe" over "risky" strategies when their choices are restricted to these options. Our setting adds to this observation via offering participants other loss-avoiding (risk-reducing) strategies, namely more collusive or more competitive capacity as well as price choices.

It is striking that participants mainly react to loss experiences by safer strategies and not by risky attempts to recover their previous losses, unlike reported by (experimental) studies inspired by prospect theory (see, for instance, Laury and Holt, 2008). This can be due to the fact that in our experimental scenarios risk reduction is costly and therefore associated with lower profits. For example, while lower prices on the one hand avoid being restricted to residual or even no demand, on the other hand they reduce total profits. Similarly, higher capacities avoid compulsory serving above capacity limits but increase sunk capacity costs and thereby also reduce total profits. It thus seems that in richer strategic settings some of the stylized results, based on (experimental) evidence from studies of individual decision making, may become debatable. However, more research is needed before reaching sound conclusions on how multiplicity of loss avoiding strategies with varying costs affects risky decision making in market contexts.

Appendix

Table 7: Effect of price coordination failures on capacity choices

	$CS=0$		$CS=1$	
Variable	**Coeff.**	**(Std. Err.)**	**Coeff.**	**(Std. Err.)**
$\bar{q}_{own}(t-1)$	0.432***	(0.035)	0.448***	(0.050)
$\bar{q}_{other}(t-1)$	0.065***	(0.019)	0.217***	(0.029)
$p_{own}(t-1)$	0.068**	(0.029)	0.044	(0.051)
$p_{other}(t-1)$	-0.034	(0.023)	0.143***	(0.031)
Too high p	-0.934	(1.016)	0.098	(1.371)
Too low p	2.569	(13.159)	1.843	(1.869)
Exp	-0.237	(1.978)	-1.779	(2.113)
fRound	-1.202	(1.034)	-2.238	(1.753)
Game	-1.134***	(0.410)	0.455	(0.486)
Constant	28.365***	(5.233)	6.339	(8.425)
Observations	2852		1571	
R^2	0.209		0.237	

Significance levels : * 10% ** 5% *** 1%
Standard errors clustered at matching group level
Includes SC, IC, CS, and R treatment

Instructions for treatment IC.R.N-M, conditions SC and CS in parentheses

General information

Thank you for participating in this experiment. Please remain silent and turn off your mobile phones. Please read the instructions carefully and note that they are identical for each participant. During the experiment it is forbidden to talk to other participants. In case you do not follow these rules, we will have to exclude you from the experiment as well as from any payment.
You will receive 15 euros for participating in this experiment. The participation fee and any additional amount of money you will earn during the experiment will be paid out to you privately in cash at the end of the session. No other participant will know how much you earned. All monetary amounts in the experiment will be given in ECU (experimental currency units). At the end, all earned ECUs will be converted into Euro using the following exchange rate:

10.000 ECU = 1 euro

Procedure of the experiment

The experiment consists of 2 parts with 12 rounds each. In each part you will make decisions at three stages. One stage consists of four rounds. You receive the instructions for the second part after finishing the 12 rounds of part 1.
At the end of the experiment, 5 rounds of each part will be randomly selected to determine your payment. You will receive the sum of your payoffs you have earned in 10 rounds. Your total payment will be comprised of the participation fee of 15 Euro and the amounts you earned in the 10 randomly selected rounds.
If you suffer a loss in the 10 selected rounds, you can pay it in cash or balance it by completing additional tasks at the end of the experiment. Please note that these additional tasks can only be used to compensate for possible losses, but not to increase your earnings. Additionally, you will receive a payment for one task from the questionnaire part. Hence, you will receive the participation fee and payment for the questionnaire part in any case.

Introduction

In this experiment you take the role of a manager in a company. You decide how many units of a good your company should produce. This amount specifies the capacity of your company. Afterwards, you choose the selling price for the produced good. Your company has a competing company which produces the same good. You compete against the other company in four rounds. Afterwards, another competitor will be randomly assigned to you. You will not be informed about the other manager's identity.

In each round of the experiment, you will first make decisions about the capacity, followed by decisions about the price. At the beginning of each round, you and the company you are competing with will decide about your capacity simultaneously (SC: one after another) and independently of each other. The capacity corresponds to the amount of goods that your company is planning to produce in this round. Every capacity unit costs a fixed amount. (CS: Your capacity determines how much you can sell in one round without additional costs. If you have to sell more than your capacity, every additional unit has much higher fixed costs.) After your capacity decision, you will be informed about the capacity decision of your competing company. (SC: At the beginning of each stage, it will be decided by choice which company determines its capacity first. The other company will be informed about this decision before making its own). Afterwards, both companies choose their selling price for their good at the same time. The company with the lower price gets the chance to sell its produced amount first. The company with the higher price can sell something only if the preferred company has produced too little to sell something to every interested costumer. (CS: The company with the lower price must sell the requested amount for the given price. The company with the higher price does not sell anything.) If the prices are equal, the costumers are distributed to both companies equally (if the number of costumers is odd, it will be rounded to the next higher even number). In any case, both companies have to pay their production costs. This holds even if they have not sold anything.

Definition of the experiment - Part 1

The experiment consists of two parts which are divided into three stages. At the beginning of each stage, the groups of two companies are assigned by chance and each time anew. (Additionally, the computer chooses which company will make its decision first.)
One stage consists of four rounds, in which you interact with the same competing company. The procedure is as follows:

1. Both companies choose a capacity between 0 and 100 at the same time. The costs are 80 ECU for each capacity unit. (SC: the randomly selected company chooses a capacity between 0 and 100. The capacity decision is announced. Afterwards, the other company chooses its capacity. For both companies the costs are 80 ECU for each capacity unit.)

2. The capacity decisions are announced. (SC: The capacity decision of the other company is announced).

3. Both companies choose a price between 0 and 200 for the produced good at the same time.

4. The chosen prices are announced, the produced goods are sold and both companies come to know their earnings or losses as well as the ones of the other company.

The demand of your produced good complies with your chosen price: The more expensive the good, the less it is bought.
The number of costumers for the produced good is computed by the software and depends on price p. It equals the amount 200-p. This means that the number of costumers declines with a rising price.
Your payment is composed of your revenues minus your production costs. For every sold good you receive the chosen price and pay production costs for every produced unit. The amount you sell depends on whether your price is smaller, higher or equal to the price of the other company in your group:

a) Your price is lower.

In this case you first get the chance to sell your produced amount. For every unit sold you receive your price p. If an amount M is requested, you earn p*M. From this you have to subtract the production costs of 80 ECU per produced unit. If the requested amount M exceeds your capacity, the other company can sell something at its higher price. This will work if interested customers remain that are ready to pay the higher price. (CS: You have to sell a good to every costumer. For every sold unit you receive your price p. If an amount M is demanded, you earn p*M. From this you have to subtract the production costs. If the requested amount M exceeds your capacity, you have to pay 120 ECU for each unit produced above capacity.)

b) Your price is higher.

In this case, you only sell something if the other company has produced too little. If there are remaining customers who are ready to buy at the higher price, they will buy from you. For every unit sold you receive the chosen price. Even if you sell nothing or less than you have produced you have to pay all the production costs at the amount of 80*your capacity. (CS: You do not sell anything, but have to pay the production costs that correspond to 80*your capacity.)

c) Both prices are equal.

In this case both companies can each sell to one half of the costumers. Even if you sell less than you have produced you have to pay all the production costs. (CS: In this case, both companies each have to sell to one half of the costumers. If this amount does not exceed their capacity, costs in the amount of 80 ECU arise for each produced unit. If this amount exceeds their capacity, they have to pay 120 ECU for each unit produced above capacity.)

Therefore, your payment can be summarized as follows:

Your price*sold amount - 80*your capacity

Please note that the production costs of 80*your capacity also arise even if you sell nothing or less than you produced in one round. (CS: Please note that the amount sold can be 0 and the fixed costs rise from 80 to 120 ECU if the sold amount exceeds your capacity.)

You will receive instructions for part 2 at the end of stage 1.

Before part 1 of the experiment begins, we ask you to answer a few control questions to help you understand the rules of the experiment. This is followed by one practice round, so that you can become familiar with the structure of the experiment. If you have any questions, please raise your hand.
Instructions for part 2

Part 2 also consists of three stages. At the beginning of each stage, the groups of two companies are chosen randomly. (SC: The computer will also decide randomly which company decides first about its capacity.)
Afterwards, there will be four rounds in each stage. The process of these rounds only differs from the rounds in part 1 insofar that the companies can tell the other company the price they will determine before choosing a price. This statement is not binding, e.g., the actual decision can be different from the price which was told. If you have any questions about part 2, please raise your hand.

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